

## CIVIL & ENVIRONMENTAL ENGINEERING | RESEARCH ARTICLE

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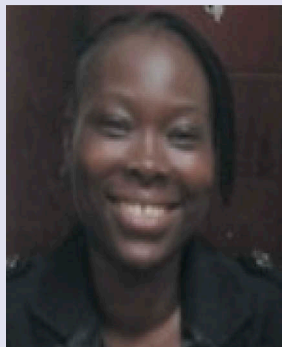
## CIVIL & ENVIRONMENTAL ENGINEERING | RESEARCH ARTICLE

# Monitoring of radon concentration for different building types in Covenant University, Nigeria

M. R. Usikalu<sup>1\*</sup>, C. A. Onumojor<sup>1</sup>, J. A. Achuka<sup>1</sup>, A. Akinpelu<sup>1</sup>, M. Omeje<sup>1</sup> and T. A. Adagunodo<sup>1</sup>

**Abstract:** Radon monitoring is essential in determining the actual level of exposure in buildings. Of all the reviewed works on indoor radon level, little to none was done on comparative radon concentration study of different building structures in the study area. A comparative study of the indoor radon concentration of different building types; such as glass house, bricks and basement house structures were done to evaluate sustainable radon level using radon detector (RAD7) machine. The mean radon concentration for glass house, brick house and basement house are 14.96, 10.74 and 144.61 Bqm<sup>-3</sup>, respectively. Glass house radon concentration range is from 11.03 to 17.46 Bqm<sup>-3</sup>. The radon concentration measured ranged from 6.62 to 20.85 Bqm<sup>-3</sup> for bricks house structure. Basement structure radon concentration ranges from 15.75 to 614.52 Bqm<sup>-3</sup>. It was observed from the study that the mean radon concentration measured from the basement structure was above the recommended limit by a factor of 4. The estimated annual effective doses are 0.377, 0.271 and 3.644 mSvy<sup>-1</sup> for glass, brick and basement houses, respectively. The study concluded that possible health risk is associated to basement structure that has limited ventilation than glass and bricks house with easy access to natural ventilation outlet. It is therefore recommended that adequate ventilation be put in place in basement house.

## ABOUT THE AUTHOR



M. R. Usikalu

Usikalu M. R. is a Lecturer and Head Radiation and Health Physics Research Cluster in Department of Physics, Covenant University. She has worked extensively on the measurement of indoor radon in different building types. Through these researches, she has been able to identify indoor radon gas exhalation level of different building types and the possible health burden on dwellers. The research outcome provides useful information for policy makers on setting guidelines for the populace on type of habitable houses and advice on sustainable ventilation choice for confined structures such as basement houses.

## PUBLIC INTEREST STATEMENT

The knowledge of indoor radon concentration level is inevitable in matters relating to sustainable environment. This is because radon gas is everywhere in the air and this can have impact on the air quality that directly influences human overall wellbeing. The exhalation of radon gas in a location depends mainly on the geological make-up of the rock, soil and different building structures in the area. In this work, a comparative study of the indoor radon gas concentration level of different building types was done in order to assess the concentration level as compared to the world set limit. The indoor radon gas level measurement was done using RAD7 detector machine. The results of the present study established that basement structure has the tendency to report elevated indoor radon value than other building types due to limited access to natural ventilation in the absence of sustainable artificial air conditioning means.

**Keywords:** radon concentration; environmental sustainability; RAD7 machine; radiation; Covenant University

## 1. Introduction

A healthy environment requires sustainability and proper ventilation which is important to sustaining safe aeration of building for dwellers. Radon gas is virtually present everywhere, however excess of it is risky to health. It is therefore important that the indoor air is clean with reduced level of radon. Radon is a progeny of primordial radionuclides of uranium and thorium as such, it is present in soils, rocks, water, buildings and construction materials. It is a radioactive gas that decays into solid. Solid particulates from radon daughters are known to be present in air and attaches to the respiratory tract when inhaled (Agency for Toxic Substances and Disease Registry (2012, 2019)). Through this mechanism, the lungs are exposed to the risks of ionizing radiation. Due to the harmful nature, radon awareness is currently on the increase globally (Nsiah-Akoto et al., 2019). Study has revealed that indoor radon concentration should be minimized to be As Low as Reasonably Achievable (ALARA) (Finne et al., 2019). However, much of this awareness is not being heard in the developing countries as few literatures still exist on the subject.

Radon is the second leading causative factor for lung cancer in the United States (Gallaway et al., 2019). It is responsible for 16% of Canadian deaths annually (Health Canada, 2014). In France, lung cancer death toll from radon is about 10% annually and cancer risk from indoor radon has increased to about 16% per 100 Bqm<sup>-3</sup> (Airouche et al., 2018). For Armenia, Hungary, Poland and Turkey, the lung cancer deaths attributable to radon are 6.1%, 6.2%, 7.0% and 5.9%, respectively (Gaskin et al., 2018). About 16.6% of lung cancer cases in Alberta resulted from indoor radon (Grundy et al., 2017). While an estimate of 12% was recorded in Norway (Finne et al., 2019). Study has proved that around 50% of exposure to ionizing radiation in Norway is traceable to indoor radon (Finne et al., 2019). In the United States about 21,000 deaths per annum were recorded against indoor radon (Benavente et al., 2019; Gaskin et al., 2018). Increased knowledge about the harmful effect of indoor radon has prompted several countries to incorporate radon control in their buildings. Meanwhile, some homes proved difficult to accept the policy (Maestre & Irribarren, 2019; Zhang et al., 2011).

Increased insights about geological variations with regard to radon concentration will enhance minimal exposure. According to (Nsiah-Akoto et al., 2019) indoor radon in Ghana ranged from 10.0 to 466.9 Bqm<sup>-3</sup>. In Poland indoor radon ranged between 6 and 139 Bqm<sup>-3</sup> (Tchorz-Trzeciakiewicz & Olszewski, 2019). Approximately 11% of residential dwellings in United States were noted to have above 100 Bqm<sup>-3</sup> of radon level (Zarnke et al., 2019). Study has shown that indoor radon can vary significantly among dwellings located in the same floor of the same building and the same soil types (Tchorz-Trzeciakiewicz & Olszewski, 2019). The implementation of energy saving measures in buildings has been observed to reduce air exchange in homes and consequently increasing indoor radon build up (Meyer, 2019). Winter and rainy seasons have also been marked with elevated indoor radon compared to summer (Bangotra et al., 2019; International Atomic Energy Agency (2013, 2019)). The authors attributed the indoor radon increase to reduced air exchange due to prolonged closure of windows during winter. They further noted changes in radon exhalation from soil as an influencing factor.

Indoor radon is known to vary from buildings to buildings and it can be elevated in house of all types (Agency for Toxic Substances and Disease Registry (2012, 2018, 2017, 2018)) especially, in the environment that has been previously noted to be rich in primordial radionuclide content (Achuka et al., 2017; Oyeyemi et al., 2017; Usikalu, Oderinde et al., 2018) which can influence radon concentration level in buildings. The impact of radiation, radon gas and possible health burden of other radiological parameters assessment (Olise et al., 2013; Usikalu, Fuwape et al., 2017; Usikalu, Rabiou et al., 2017) reveals the need for monitoring of radon gas level of inhabited structures. The convenience and safety of dwellers are primarily influenced by structural and non-structural elements. Building material

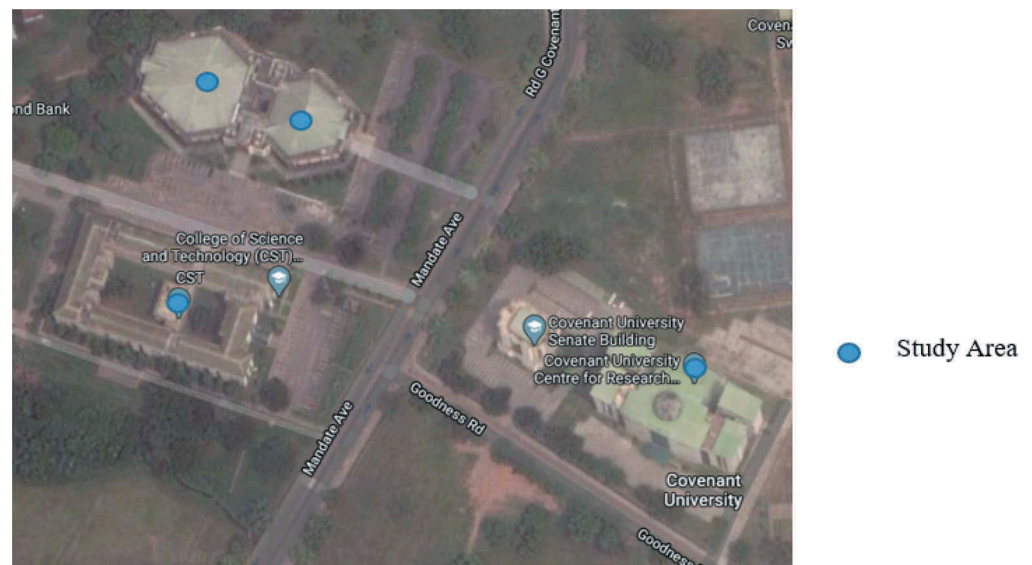
assessments (Omeje et al., 2018) are part of the structural radiological safety measures that can reduce elevated radon level in homes and offices. The relationship between house dwellers safety to safe-culture of contractors working in construction industries and the final structural output of any building was established by United Nations Scientific Committee on the Effects of Atomic Radiation (2019, 2019, 2000). It was concluded that the healthy state of the building is not directly proportional to the health and convenience of the inhabitants. Hence, becoming more knowledgeable of potential risk, possible hazards and safety alertness of building structures go a long way to reduce or eliminate risk factors (Gallucci Raymond, 2018; Javadi & Komjani, 2017; Kyere et al., 2018). Of all the reviewed works on indoor radon level, little to none was done on comparative radon concentration study of different building structures most especially in the region of study. Since exposure level of indoor radon can be remediated, it is essential to ensure sustainable minimal indoor radon in all residential dwellings in the study area. Hence, this study was embarked upon in order to determine the level of radon concentration in different house types in the study environment. Thereby enhancing tolerable indoor radon in homes that will generates healthy and sustainable environment. The next section discussed the material and method used, clearly stating the set-up arrangement for reproducibility purpose. The results obtained are presented and discussed next and finally the deduced conclusion was presented.

## 2. Materials and method

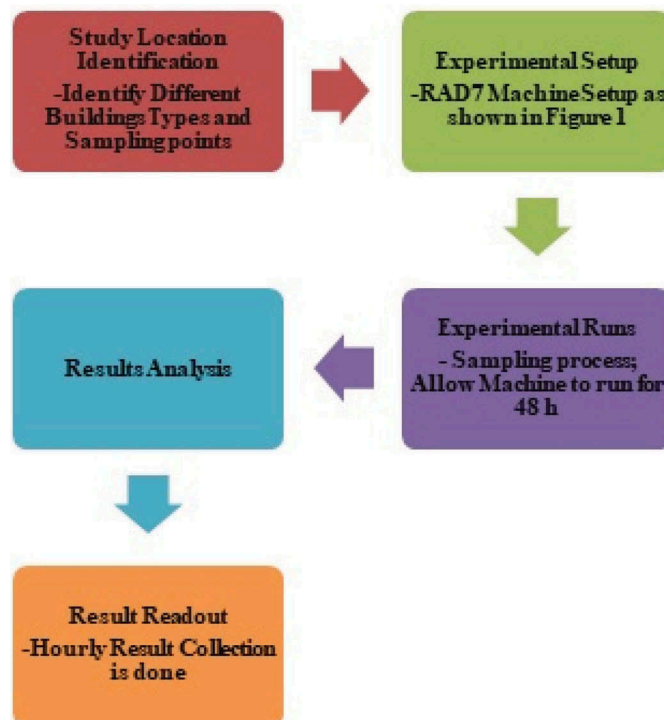
### 2.1. Study area

The study area locations are in Covenant University, Ado-Odo Local Government Area of Ota. It is a town in Ogun state, Nigeria with latitude 6E 37'N, longitude 3E 42'E and altitude 41 m. The study area has several building types; the glass, brick houses and basement house structures. Sustainable radon study in different building types was carried out from October 2018 to March 2019. The selected building structures for the present study are; the College of Science and Technology (CST) which is made of bricks structure denoted by (CFGF to CFL3), Covenant University Center for Research and Innovation (CUCRID) is mainly a glass house denoted by CRGF–CRF5 and basement offices of Lecture Theatres denoted by LT1–LT5. Figure 1 shows the google satellite map capture of study area. The Lecture Theatre (LT) is the twin building above the CST building as displayed on the satellite map shown in Figure 1. Figure 2 is the flow chart presented to show the step by step methodology of the research work for research duplication ease. The first step was to select study location and identify sampling points. Next step was the experimental setup of RAD7 machine as shown in Figure 3. This is followed by sampling process, result data acquisition, analysis and readouts.

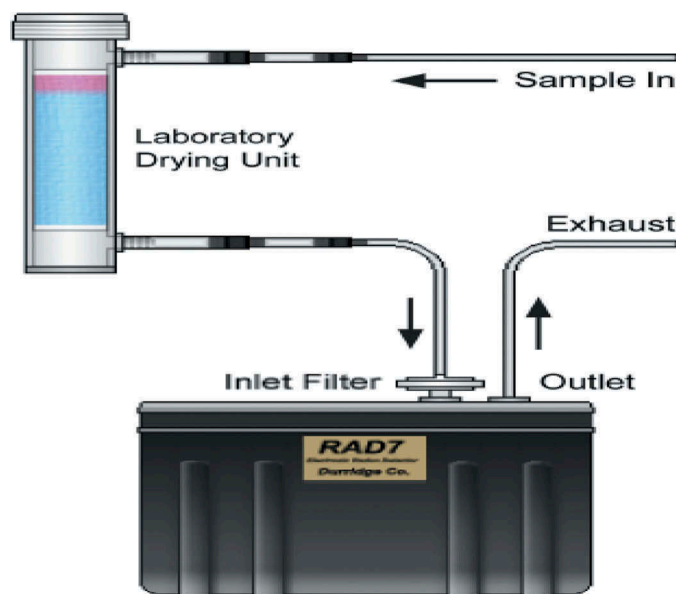
**Figure 1. Satellite map of study area.**



**Figure 2. Flow chart of research method process.**



**Figure 3. DURRIDGE RAD7 radon monitor.**



The choice of selecting these locations for the study is to allow for comparison of radon concentrations in different building structures. CUCRID building construction material is mainly glassware (also called glass house). It is a five (5) story building that comprises several offices and laboratories. CST was built with bricks; it is a four (4) story building that also houses several laboratories and offices. LT is a study location with basement structured office areas under the LT. In this research, an indoor radon accumulation of the story building office floors and basement



offices were measured. The instrument used for the measurement is the calibrated DurrIDGE portable continuous radon monitor called RAD7 operated in Auto mode (combination of sniff and normal mode), 2-day protocol (48 h sampling time). RAD7 device analyzed results obtained by alpha spectrometry. Only the radon gases are measured in the measurement chamber and it is then recorded. The DurrIDGE RAD7 uses a solid-state alpha detector with silicon as the detector's semiconductor material for efficient conversion of alpha radiation directly to readable electrical signal.

## 2.2. Sampling set-up

The RAD7 machine was taken to each sampling location and set up as shown in Figure 1. Operation set-up was 2-d protocol set on auto mode. The RAD7 machine was allowed to Test-Purge for ten (10) minutes before the sampling test run commenced at each study location. Test-purge was done to clear the sample chamber of any residual radon and its progeny that were trapped in sample chamber from previous sampling which could influence the current test result. The 10 min test-purge was done with the RAD7 machine connected to a clean desiccant (air sample drying unit) that allowed radon-free air to flow into the sample chamber via the inlet as shown in Figure 3. The radon-free air cleared off previously sampled radon during test-purge. The total sampling time for a location is 48 h. Radon concentration results were auto-printed out by RAD7 on hourly basis for the 48-h sampling time.

RAD7 detector was used to measure radon gas concentration for each study location. RAD7 set-up allowed it to pull in air sample from the environment through the clean inlet filter into the RAD7 chamber for analysis. Radon progeny were filtered away and only radon gases in air sample entered to the chamber. At the chamber, Radon gas concentrations were measured and results were displayed on the machine screen for printing. Auto hourly printing of result was possible when the printer was linked to the machine to do so.

## 2.3. Dose estimation

The annual effective dose (H) to staff using the offices was calculated using equation 1.

$$H(\text{mSv}\cdot\text{y}^{-1}) = cr \times f \times t \times dcf \quad (1)$$

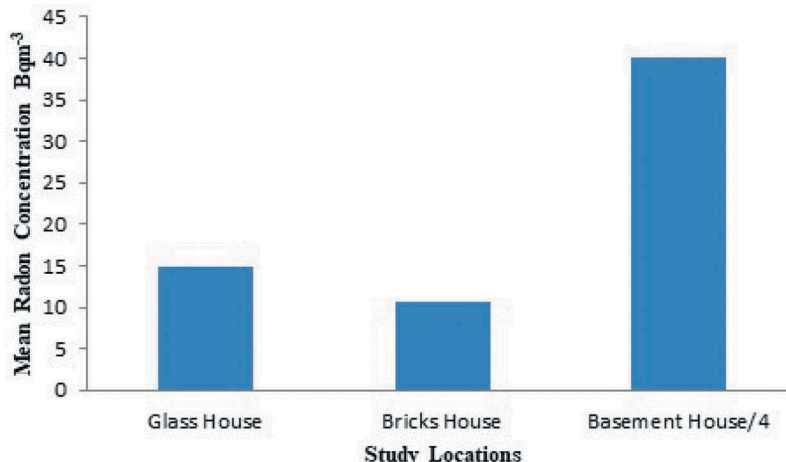
$H$  is the annual effective dose,  $cr$  is the mean radon concentration,  $f$  is the equilibrium factor for radon (0.4) and its progeny,  $t$  is the indoor occupancy factor taken  $7000 \text{ h}\cdot\text{y}^{-1}$ , and  $dcf$  is dose concentration factor ( $9 \text{ nSv}\cdot\text{h}^{-1} (\text{Bq}\cdot\text{m}^{-3})^{-1}$ ) for radon and its progeny (ICRP, 2009).

## 3. Results and discussion

The indoor radon concentration of three types of buildings in Covenant University was studied. The different building/house types are bricks house, glass house and basement house. All these building types are used as office spaces for staff of the university. The average radon concentration values and the corresponding temperature for the three studied building types are presented in Table 1. Other measured indoor parameters include room temperature and relative humidity. The knowledge of radon concentration level in these different types of building is paramount to assure the safe stay of workers as related to their health and wellbeing. Maintaining safe level of radon concentration in the buildings is one of the sustainability plans for safe physical work environment for the institution staff and faculty members. The mean radon concentration for glass house, brick house and basement house are  $14.96$ ,  $10.74$  and  $144.61 \text{ Bq}\cdot\text{m}^{-3}$ , respectively. Glass house radon concentration range is from  $11.03$  to  $17.46 \text{ Bq}\cdot\text{m}^{-3}$ . The radon concentration measured for bricks house structure ranged from  $6.62$  to  $20.85 \text{ Bq}\cdot\text{m}^{-3}$ . Basement house radon concentration ranges from  $15.75$  to  $614.52 \text{ Bq}\cdot\text{m}^{-3}$  as presented in Table 1. Location CRF3 recorded the highest average value of  $21.82 \text{ Bq}\cdot\text{m}^{-3}$  for the glass house. This location is on the third floor. The high value may be due to the lack of air condition which reduces the ventilation on this floor. CGF has the highest value of  $20.85 \text{ Bq}\cdot\text{m}^{-3}$  for bricks house. This is not surprising as the location is on the ground floor and radon emanate from the earth crust (Banjanac et al., 2006; Usikalu, Olatinwo et al., 2017). LT4

Table 1. Radon concentration for three different building types						
	Location ID	Mean Radon Concentration Bqm <sup>-3</sup>		Location ID	Mean Radon Concentration Bqm <sup>-3</sup>	Location ID
Glass House	CRGF	11.98	Bricks House	CGF	20.85	LT1
	CRF1	17.46		CFL1	7.16	LT2
	CRF2	11.03		CFL2	12.27	LT3
	CRF4	18.73		CFL21	6.83	LT4
	CRF5	15.59		CFL3	6.62	LT5
	Mean	14.96		Mean	10.74	Mean
			Basement House			

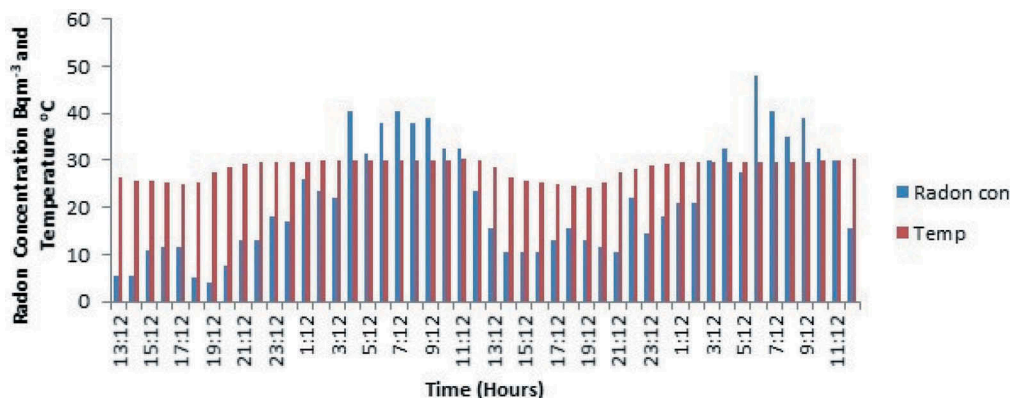
**Figure 4. Mean radon concentrations for the three studied building types.**



recorded the highest value of 614.52 Bqm<sup>-3</sup> for basement structure. This is due to lack of natural ventilation in this location. Comparing the obtained results with the world recommended limit of 40 Bqm<sup>-3</sup> (United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2000), all results were below the recommended limit except location LT4 of the basement structure which went above the limit with a factor of 15.36. Figure 4 shows the mean radon concentrations for the three studied building types. It is the pictorial representation of radon concentration for the three buildings. There is a wide gap between the radon concentration values obtained from basement house when compared with all the building as clearly shown. Study location LT4 is an office space at the middle of the basement office space structure with no access to the outside or outdoor world. Hence LT4 has no outdoor air inlet access like the other basement office spaces with window access for outdoor air inlet. The window opening of LT4 opens to the indoor spaces of the basement. The LT4 position and lack of outdoor air access are possible contributions to the high radon concentration levels.

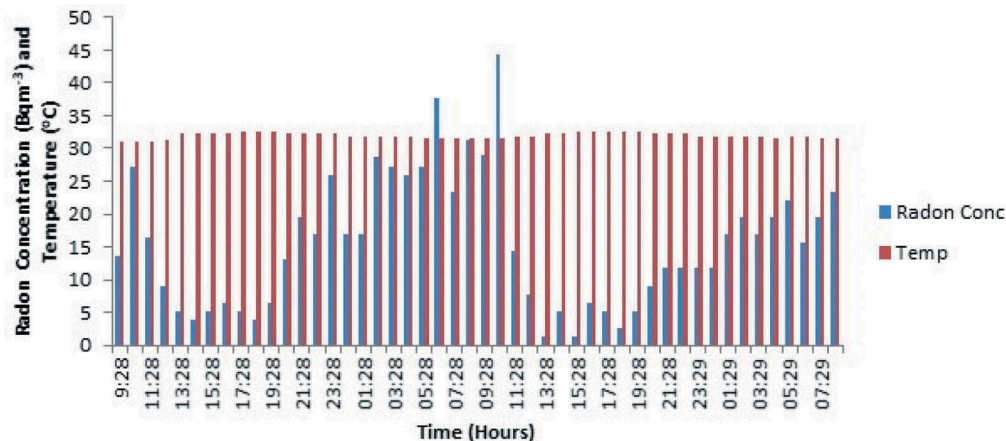
Figures 5–7 show the plot of other influencing parameters on indoor radon concentration. From the plots, a comparison of temperature shows a regular influence pattern at room temperature range of 26–31°C during the 48-h sampling time for all building types. The radon concentration rises and drops pattern is similar to a sinusoidal wave pattern with the crest representing the period when the office spaces are not in use. This implies that the office spaces are closed. The trough represents the period when the office spaces are in use with functional AC or active inflow of outdoor air via open windows. The

**Figure 5. Comparison of radon concentration with temperature in CUCRID-glass house.**

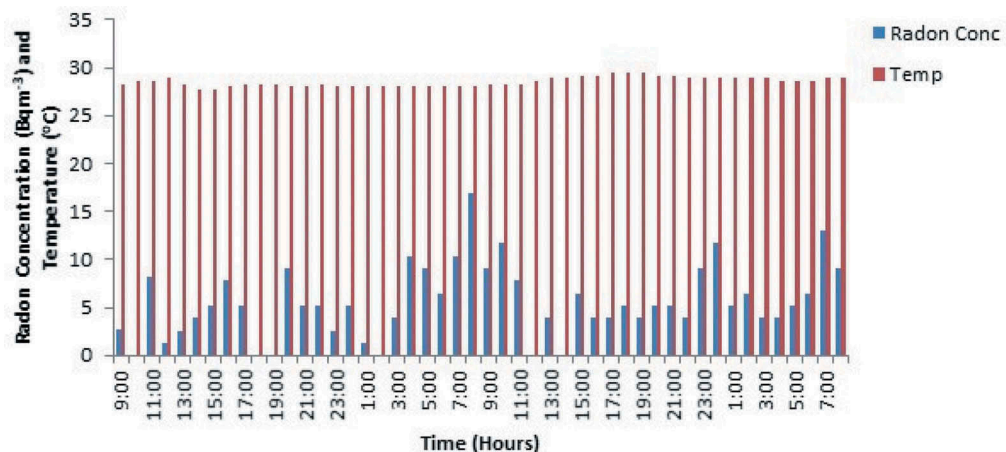




**Figure 6. Comparison of radon concentration with temperature in CST-bricks house.**

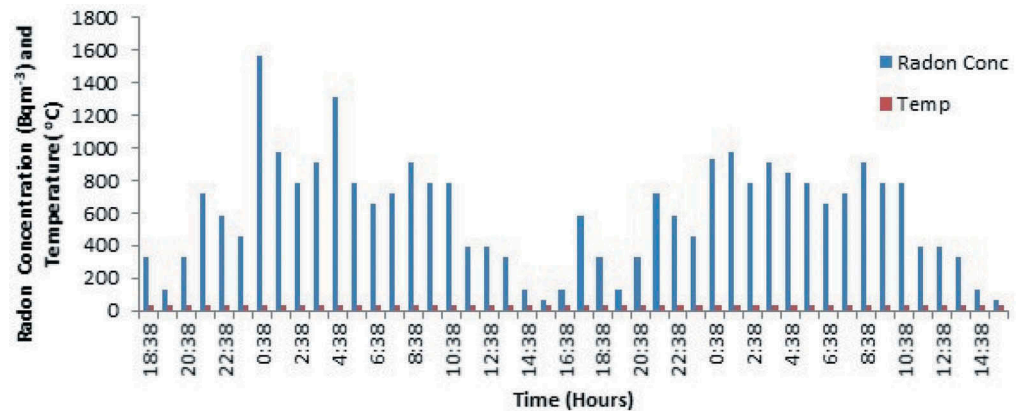


**Figure 7. Comparison of radon concentration with temperature in basement house.**

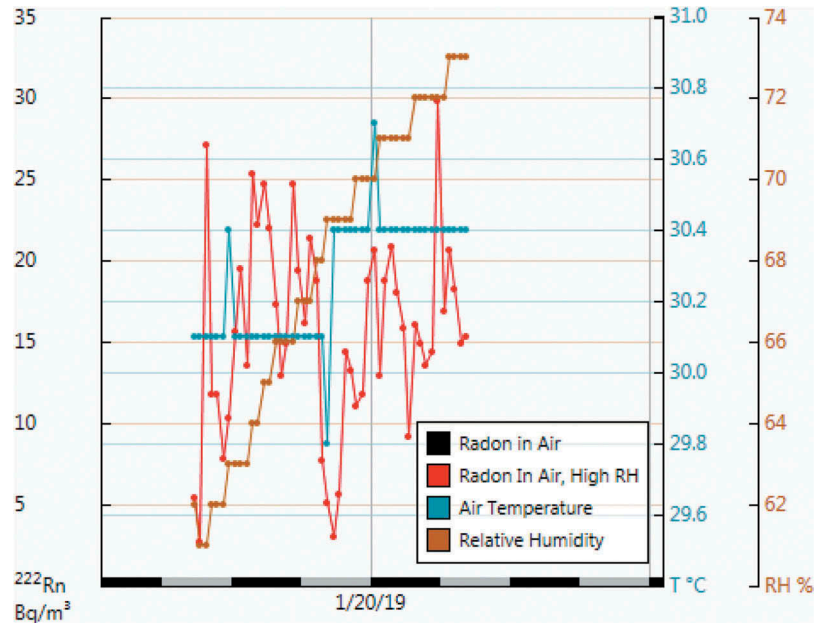


office space at the center of the basement structure has the same crest and trough pattern but with radon concentration far higher than the average world recommended limit of  $40 \text{ Bqm}^{-3}$  as shown in Figure 8. The result of the mean concentration obtained in this study is comparable with other studies conducted within and outside Nigeria (Bangotra et al., 2019; Nsiah-Akoto et al., 2019; Usikalu, Olatinwo et al., 2017; Usikalu, Onumojor et al., 2018). The radon concentration measured was used to estimate the annual effective dose, the mean annual effective dose calculated are 0.377, 0.271 and 3.644 for glass, brick and basement houses, respectively. The annual effective dose of basement house was found to be higher than the world limit by a factor of 3.17, while glass and brick house are within recommended limit. The temperature of the different building types is approximately the same. From the radon concentration results, it was observed that it has little or no influence on radon level in the different office spaces. Another parameter observed in the current study was relative humidity. Figures 9–11 show the RAD7 comparative capture software plots of temperature, relative humidity parameters and their influence on radon concentration level. From the plots, it was observed that relative humidity has potent influence on radon concentration than temperature. Increased relative humidity from proper ventilation resulted in reduced radon concentrations. The plots show the regular reduction pattern of radon level with rise in humidity. It was observed that temperature has little or negligible influence on radon compared to relative humidity. The influence of temperature on radon concentration level was obtained by determination of the correlation factor  $R$  as shown in Figure 12.  $R$  was far less than 0.05 in all building types. The correlation is in the positive direction (positive correlation). This implies that temperature change influences radon gas exhalation in buildings. The influence can be said to go from little to

**Figure 8. Comparison of radon concentration with temperature at basement house center office space.**

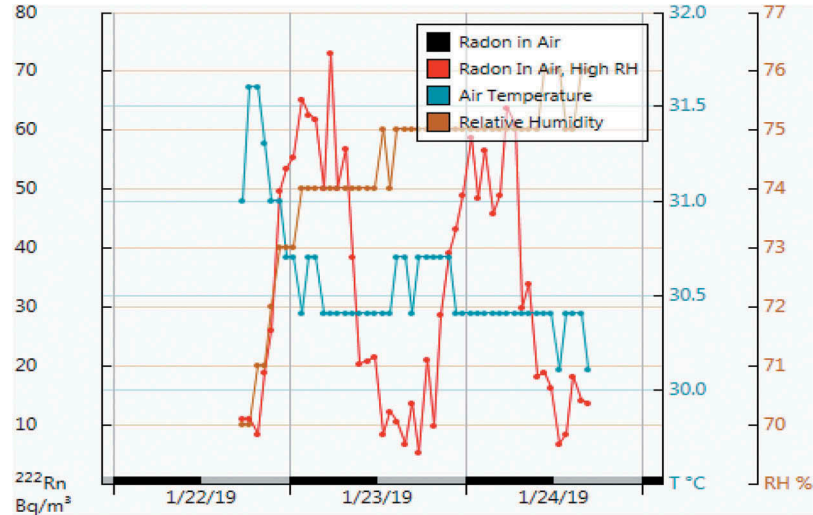


**Figure 9. Plot of radon level and influencing parameter for glass house.**

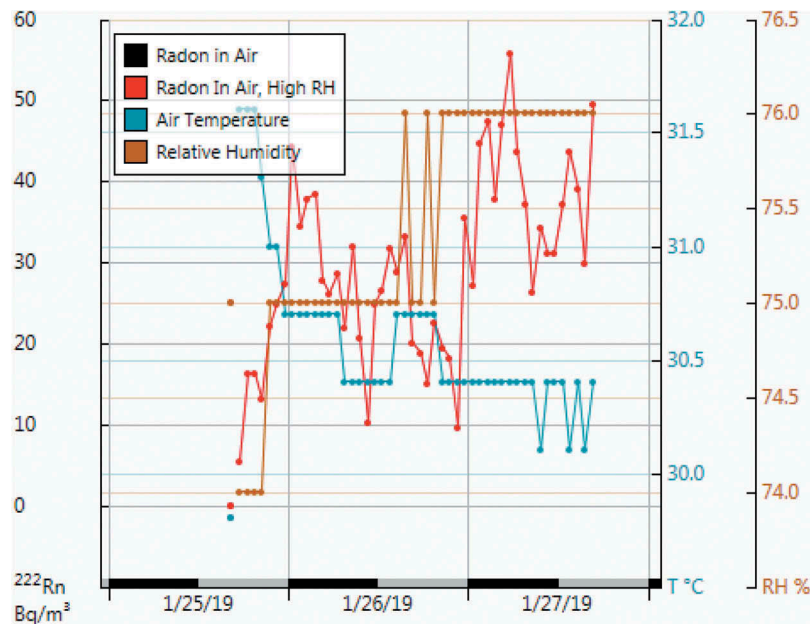


negligible. That is, as building temperature rises, radon gas exhalation is expected to increase at unnoticeable rate. Figure 13 shows a comparative study of the present research to previous studies and world standard. The varying values of mean radon concentration of the different studies could be due to several radon influencing factors and one major factor is the various geology of each study place. A total of eight previous studies were compared with the results obtained in the present study. Figure 13 legend clearly shows the previous studies (Baeza et al., 2003; Banjanac et al. 2006; Hernandez et al., 2007; Maged., 2006; Oikawa et al., 2006; Planinic et al., 1995; Rahman et al., 2010; and Usikalu, Onumejor et al., 2018) in blue, the present study in red and the world standard limit in green. Plot bars higher than the green bar with values  $40 \text{ Bq m}^{-3}$  (United Nations Scientific Committee on the Effects of Atomic Radiation (2000, 2009)) are above world set limit, while those on the same level and below are within the safe world standard limit level. The present study reported elevated mean radon concentration value for basement house. This is unsafe for dwellers if the house state remains in the same state (Figure 13). The brick and the glass building radon concentration measurement of the study area are within world standard value. This therefore implies that there is no radon potential risk on dwellers. Therefore, the present results compared well with previous indoor radon studies.

**Figure 10. Plot of radon level and influencing parameter for bricks house.**



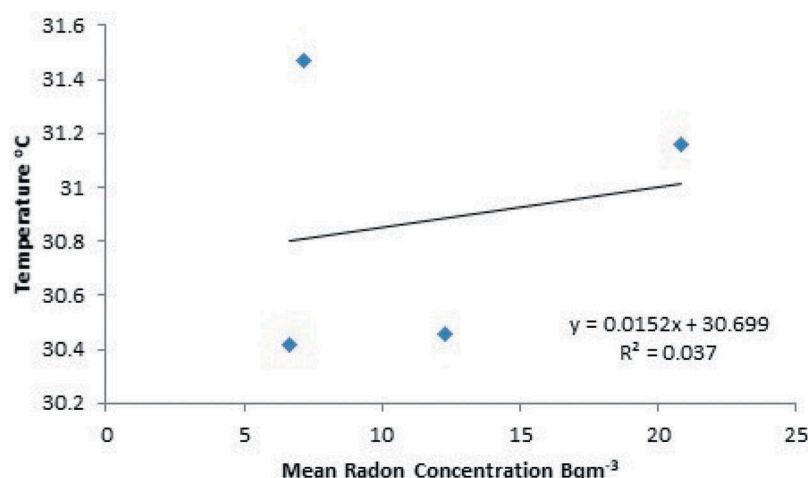
**Figure 11. Plot of radon level and influencing parameter for basement house structure.**



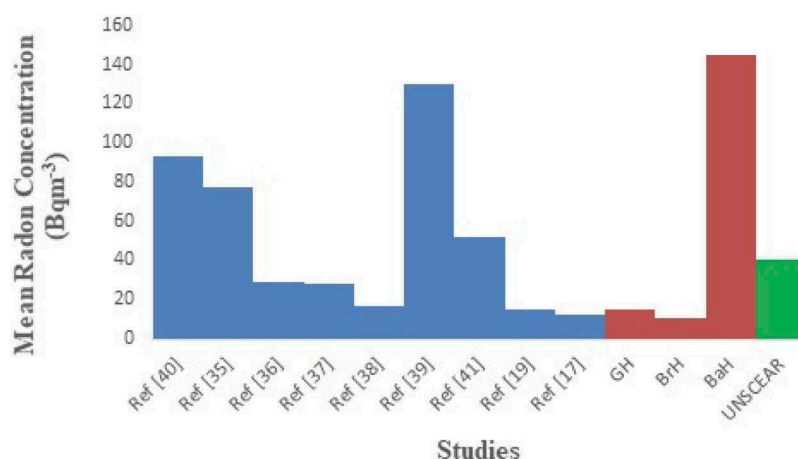
#### 4. Conclusion

Radon concentration of different building types such as glass house, bricks and basement house structures were studied to evaluate sustainable radon level as pathway for environmental sustainability. The mean radon concentration for glass and brick house was within the recommended limit with the exception of the basement house. It was found that the basement structure concentration went above the limit by a factor of 4. Consequently, it can be said that the radon level in the brick and glass building in this study does not pose any risk to dwellers with the exception of the basement building that went above the set limit. The annual effective dose of basement house was found to be higher than the world limit by a factor of 3.17, while glass and brick house are within recommended limit. It was also observed that the relative humidity has potent influence on radon concentration than temperature. There should be implementation of radon sustainability operational structures in all the buildings and proper awareness of workers to the risk posed by high radon accumulation in the work place. Those in

**Figure 12. Correlation of radon level and temperature in locations of study.**



**Figure 13. Comparison of radon concentration with previous studies.**



the basement offices are exposed to increased radon risk due to limited ventilation than those in glass and bricks house with easy access to natural ventilation outlet. In order to mitigate radon off shot and sustainability of safe radon concentration level in all the buildings, proper aeration of the building structures, most especially the basement house should be enforced. The study recommended periodic radon level monitoring to ascertain minimal radon risk to staff.

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#### Cover image

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